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EFFECTIVE STIMULATED SCATTERING IN THE ULTRAVIOLET AND DISPERSION OF GAIN IN THE 1.06 - 0.26 μ BAND

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1. We obtained effective Raman and Mandel'shtam-Brillouin scattering in the UV region and investigated some of their characteristics. The increase of the Raman susceptibility in the UV region has made it possible to develop an effective Raman laser using liquid nitrogen with pumping at $\lambda = 0.26$ μ (using a pump power of 10 kW in a system without mirrors, we were able to excite Stokes generation with an efficiency reaching several dozen per cent). Noticeable increase of the gain in the UV region was registered also for SMBS.

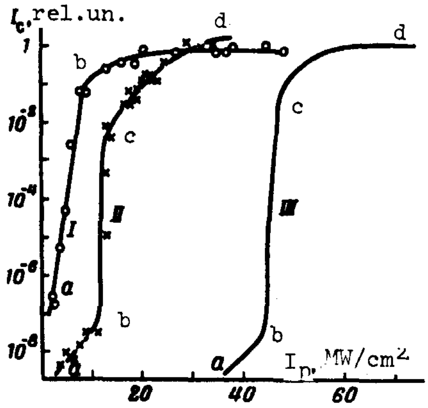
2. The exciting radiation was a stable fourth harmonic of a neodymium laser operating in a regime where one longitudinal and one transverse mode is generated (see [1]). The use of a cascade scheme has made it possible to have simultaneously single-mode emission at $\lambda_1 = 1.06$ μ, $\lambda_2 = 0.53$ μ, $\lambda_3 = 0.35$ μ, and $\lambda_4 = 0.26$ μ. The stability of the fourth harmonic output power was not worse than 10%. The maximum fourth-harmonic energy reached 0.1 J.

3. The working medium for the Raman laser with UV pumping was chosen to be liquid nitrogen (see [2, 3]). It turns out that SRS with $\lambda_p = 0.26$ μ is quite effective; when a lens (F = 17 cm) is used, a nonlinear scattering regime (the efficiency of conversion into the Stokes components exceeded 10%) could be obtained at $P_p \approx 100$ kW (three intense Stokes components were excited simultaneously). At $P_p \approx 1$ MW, up to five Stokes components and one anti-Stokes components were excited.

The SRS gain in the UV region was measured in a parallel beam. The figure shows the experimental dependence of the intensity of the first Stokes component I_s on the pump intensity I_p (length of cell with nitrogen $\ell = 13$ cm). Assuming that the linear section of the curve, measured at $I_s/I_p \ll 1$, is described by the formula

$$I_s = I_{s0}\exp(gI_{\parallel}\ell), \tag{1}$$

we can determine the growth factor g. For comparison, we present the results obtained by us at $\lambda_p = 0.53$ and the results of [3] (see Table 1).



Experimental plots of the intensity of the first Stokes SRS component in liquid nitrogen vs. pump intensity, measured for different pump wavelengths in a parallel beam. Length of cell with nitrogen $\ell = 13$ cm. I) $\lambda_p = 0.26$ μ, II) $\lambda_p = 0.53$. The plot for $\lambda_p = 0.69$ μ (III), borrowed from [3] and measured in a parallel beam in a cell of length $\ell = 6$ cm, is shown for comparison.

TABLE 1

Values of the growth coefficient g in liquid nitrogen at different wavelengths

λ, μ	g_{exp}, cm/MW	g_{theor} cm/MW
0.265	$15.0 \cdot 10^{-2}$	–
0.530	$3.0 \cdot 10^{-2}$	$2.4 \cdot 10^{-2}$
0.694	$1.6 \cdot 10^{-2}$	$1.7 \cdot 10^{-2}$

4. Another characteristic feature, besides the already noted decrease of the factor g in the UV region, is the different character of the gain curves. In parallel beams at $\lambda_p = 0.53$ and 0.69 μ, the gain curve consists of three characteristic sections: a section of "normal" exponential gain (a, b) (it is in this section that the value of g is determined), due to instabilities which have not been established uniquely (see, for example, [3]); a "jump" (b, c), where the effective value is $g_{eff} \sim 10$ cm/MW, and a saturation section (c, d). No "jump" is observed at $\lambda_p = 0.26$ μ. This, in our opinion, eliminates feedback due to Rayleigh scattering as a possible cause of the jump. These data, taken together with our experiments with focused beams, offer evidence that the position of the jump on the gain curve is determined by the total pump power, and that the most probable mechanism explaining the "jump" is self-focusing (see also [4][1])).

5. An important characteristic of a Raman laser, besides the gain g, is the threshold pump power P_{thr}. For a mirrorless scheme, the threshold is clearly pronounced if the gain curve has a "jump." Table 2 gives the values of P_{thr} measured by us for pump wavelengths (the geometry remains unchanged).

TABLE 2

Threshold powers necessary to obtain a nonlinear regime in a liquid-nitrogen Raman laser operating in the superluminescence regime ($\ell = 13$ cm).

λ, μ	1.06	0.53	0.35	0.26
P, MW	13.00	4.00	1.60	0.50

6. An appreciable lowering of the threshold on going to the ultraviolet spectrum region was observed for backward SMBS in crystalline and fused quartz. The results are summarized in Table 3. The data for $\lambda_p = 1.6$ μ and $\lambda_p = 0.35$ μ are in satisfactory agreement with the data of [6].

Worthy of attention is the hitherto-unexplained fact that there is no SMBS at $\lambda_p = 0.26$ μ in fused quartz and ADP, which are transparent at this wavelength. An analogous phenomenon was observed also in the frequency dependence of the Raman susceptibility. We were unable to observe SRS at $\lambda_p = 0.26$ μ in cyclohexane, methyl cyclohexane, and a few other liquids.

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[1]) Strong self-focusing in liquid nitrogen at a pump power not exceeding 10 MW was distinctly observed, besides in [4], also in experiments with picosecond UV pulses [5], where it could be readily revealed by the specific structure of the broadened spectra.

TABLE 3

Threshold pump energies (J) for backward SMBS excited by a focused laser beam (F = 5 cm)

Material	λ = 1.06 μ	λ = 0.53 μ	λ = 0.35 μ	λ = 0.26 μ
Cryst. quartz (beam axis)	$7 \cdot 10^{-3}$	$1.5 \cdot 10^{-3}$	$1.1 \cdot 10^{-3}$	$1.2 \cdot 10^{-3}$
Crystl. quartz (extraord.wave)	$12 \cdot 10^{-3}$	$5.0 \cdot 10^{-3}$	$2.0 \cdot 10^{-3}$	$1.2 \cdot 10^{-3}$
KU quartz (fused)	$12 \cdot 10^{-3}$	$3.0 \cdot 10^{-3}$	$3.0 \cdot 10^{-3}$	no (to $5 \cdot 10^{-2}$)
ADP (extraord. wave)	no (to 2.5 J)	$1.4 \cdot 10^{-3}$	$3.2 \cdot 10^{-3}$	no (to $5 \cdot 10^{-2}$)

These phenomena may be caused by competition on the part of nonlinear absorption.

7. Simultaneously with the study of the SMBS we investigated the frequency dependence of the threshold characteristics and the character of the optical breakdown in the substances listed in Table 3.

On going from λ = 1.06 μ to λ = 0.26 μ, one can see particularly clearly a change in the character of the breakdown, from "pointlike" damage at long wavelengths to filamentary damage at shorter ones (this fact was noted earlier by Zverev and co-workers [7], who carried out investigations in the 1.6 - 0.35 μ interval).

The breakdown threshold drops quite rapidly with decreasing wavelength; at the same time we were able to observe SMBS in the 1.06 - 0.53 μ band without destruction of the material.

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